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TITLE: Electromagnetic Properties of High T(C)

Superconductors

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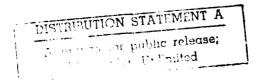
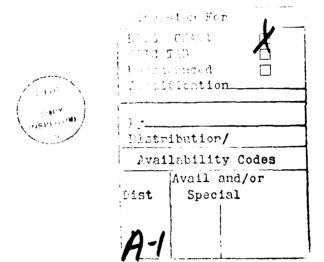


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STATEMENT "A" per Dr. Michael Shlesinger ONR/Code 1112 TELECON 9/27/90 VG

PROJECT DESCRIPTION

During the first part of the grant period, we have focussed on the nonlinear and frequency dependent response of strongly disordered materials.

We have chosen the alloy system $Ge_{1-x}Au_x$ for detailed studies of the dynamics because the static properties, and the development of the localized states with decreasing temperature are well understood and specimens can be prepared at UCLA using an evaporator available to us.

We have measured the electric field dependent of the conductivity $\sigma(E)$ for some $Ge_{1-v}Au_v$ evaporated alloy films near the metal-insulator transition. In our work this occurs near the nominal composition x =0.12. Both dc and pulsed field methods were used.

We have found that the conductivity is strongly nonlinear at temperatures, and have interpreted our results in terms of electron heating effects.

INVISION OF CONCERNS-During the second part of the grant period we have been investigating the high frequency properties of various high Tc superconductors. The key parameter which is studied in the micro- and millimeter wave spectral range is the surface impedance $\mathbf{Z}_{(S)}^{\cap}$. It is one of the parameters which reflects the electrodynamics of the superconducting state. At the same time it is perhaps the most important technical parameter which determines the application potential of the superconductors for high frequency passive components and devices. KEYDOK-C: Superside Components and devices. KEYDOK-C: The surface impedance is defined as

$$Z_{S} = \frac{E_{O}}{\int_{O}^{\infty} j dx}$$
 (1)

where E_{O} is the electric field of the surface, j the ac current in the sample and the x direction is perpendicular to the surface. Zs is, in terms of the complex conductivity σ = σ_1 - $i\sigma_2$, given by

$$z_s = \left(\frac{\mu_0 \omega}{\sigma_1 - i\sigma_2}\right)^{1/2} = R_s + iX_s \tag{2}$$

where μ_{O} is the permeability of free space, R_{S} and X_{S} are the surface resistance and surface reactance, and ω the measuring frequency.

The surface resistance has been calculated in the local limit by Mattis and Bardeen, and $R_S(T)$ is in good agreement with experiments conducted on classical superconductors. For the high temperature superconductors, the mean free path is comparable to the coherence length ξ , and consequently finite mean free path effects are important, and have to be taken into account when experiments are compared with the various theories of the superconducting ground state.

Our experiments are conducted by using resonant structures, with the superconducting material forming part of the structure. Both cavity endwall and cavity perturbation techniques have been utilized, they give somewhat different information on $R_{\rm S}$ and $X_{\rm S}$. In all cases $R_{\rm S}$ and $X_{\rm S}$ is determined using a configuration where these parameters refer to electric currents flowing in the planes (if thin films are investigated).

 $R_S(T)$ measured by us on a ceramic, sputtered thin film and laser ablated film is displayed in Fig. 1. One observes a finite residual resistance as $T\to 0$, and $R_S(T)$ depends also strongly on the film quality, with laser ablated films — the highest overall quality — giving the lowest $R_S(T)$ values.

The large $R_{\rm S}$ for the majority of materials is due to a second phase or due to grain boundaries which act like Josephson coupling between the grains. We have developed a simple model of grain boundary effects on the surface impedance of thin films, the material is modeled as a network of superconducting grains coupled by Josephson junctions, which are described using the standard resistively shunted junction model with negligible capacitance.

For laser ablated films, grain boundary effects are not important, and $R_S(T)$ can be compared with the various theories of the surface impedance, i.e. with a calculation based on the Mattis-Bardeen model, and with calculations with finite mean free path effects with various gap values. Our experimental results lie below $R_S(T)$ arrived at for a realistic model, with $\ell/\pi\xi_O=1$ and $2\Delta=3.5k_BT_C$ (corresponding to $\xi_O=16A$ and $\ell=50A$, both parameters referring to the in-plane parameters). This suggests that Δ is larger than the weak coupling limit, and a value $2\Delta\sim5k_BT_C$ appears to describe our results well. Consequently, surface impedance studies suggest, that YBa_2Cu_3O_7 is in the strong coupling limit with Δ exceeding well the BCS value. Our results also convincingly rule out drastic deviations from a gap which opens up along the entire Fermi surface. We note however, that the experimental configuration employed by us leads to ac current in the CuO_2 planes, and consequently, no information is gained on the ac losses for current perpendicular to the planes.

Our results have obvious implications as far as the application potential of these materials is concerned. We have found that at microwave frequencies the losses can be lower by more than one order of magnitude than Cu at the same temperature both in $YBa_2Cu_3O_7$ and in the $T\ell$ based films.

I believe that future work on the high frequency properties of high temperature superconductors is fully justified. The stage is set for construction and testing of simple passive microwave devices, and to correlate the device characteristics with the loss characteristics of films and also with losses which occur in the dielectric substrates.

2. PUBLICATIONS DURING THE GRANT PERIOD

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- L. Drabeck, J. Carini, G. Grüner, T.L. Hylton, A. Kapitulnik, M.R. Beasley. "Surface Impedance of High T_C Superconductors." International Microwave Symposium, Long Beach, CA (1989).
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- 6. J. Carini, L. Drabeck. and G. Grüner. "The Surface Impedance of High T_C Superconductors." Modern Physics Letters B, Vol. 3, 5 (1989).
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- 9. L. Drabeck, K. Holczer, G. Grüner, J.J. Chang, D.J. Scalapino, A. Inam, X.D. Wu, L. Nazar, T. Venkatesan. "Surface Resistance of Laser Deposited YBa₂Cu₃O₇ Films." Phys. Rev. B, Rapid Communications.
- 10. D.W. Cooke, E.R. Gray, R.J. Houlton, H.H.S. Javadi, M.A. Maez, B.L. Bennett, B. Rusnak, E.A. Meyer, P.N. Arendt, J.G. Beery, R.D. Brown, F.H. Garzon, I.D. Raistrick, A.D. Rollett, B. Bolmaro, N.E. Elliott, N. Klien, G. Muller, S. Orbach, H. Piel, J.Y. Josefowicz, D.B. Rensch, L. Drabeck, and G. Grüner. "Surface Resistance of YBa₂Cu₃O₇ Films Deposited on LaGaO₃ Substrates." Physica C 162-164, 1537 (1989).
- 11. W.L. Olson, M. Eddy, T. James, R. Hammond, G. Grüner, and L. Drabeck. "Preparation of Superconducting T1-Cu-Ba-Cu Thin Films by Chemical Deposition." Appl. Phys. Lett. <u>55</u>, 188 (1989).

- 12. T. Frey, St. Siegmann, H.J. Günthfrodt, L. Drabeck, G. Grüner. "In-situ Deposited Superconducting Laser Ablated Thin Films of $YBa_2Cu_3O_x$ and $Bi_{0.8}PS_{0.2}Sr_{0.8}Ca_1Cu_{1.6}O_x$." Denver Conference on High T_c Films, 1990.
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- 15. L. Drabeck, K. Holczer, G. Grüner and D.J. Scalapino. "Ohmic and Radiation Losses in Superconducting Films." Journal of Applied Physics, (to be published).

3. PERSONNEL SUPPORTED BY THE GRANT

1. Dr. John Cooper Postdoctoral Associate

2. Dr. John Carini Postdoctoral Associate

3. Ward Beyermann Graduate Student

4. Sang Woog Cheong Graduate Student

5. Larry Drabeck Graduate Student

4. FINAL INVENTORY OF PROPERTY

None

5. FINAL PATENT REPORT

None